

**5<sup>rd</sup> Quarterly Status Report**  
**Liquid-Phase Deposition of  $\alpha$ -CIS Thin Layers**  
**Contract # XDJ-3-30630-33**

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Since the submission of our last quarterly/annual status report, we have deposited Cu–In–Se films by utilizing the “sliding boat” technique, as previously described. The newly adopted technique has proven to work very well in depositing Cu–In–Se films from the melt. For all films deposited so far, the chemical composition of the starting ingot material has been  $\text{Cu}_{33.3}\text{In}_{33.3}\text{Se}_{33.3}$ . From the results previously reported, this composition lies in the largest primary phase field of the liquidus projection of the Cu–In–Se ternary equilibrium phase diagram in which  $\alpha$ -CIS is the first phase to precipitate from the growth solution. Table 1 lists the compositions of the

Sample ID #	Film Composition (at%)
SBD 1	21.6 : 25.9 : 52.5
SBD 2	22.7 : 36.1 : 41.2
SBD 3	17.8 : 12.6 : 69.6
SBD 4	23.9 : 29.9 : 46.1
SBD 5	30.7 : 26.9 : 42.3
SBD 6	6.2 : 47.1 : 46.7
SBD 7	25.2 : 26.4 : 48.3
SBD 8	23.6 : 29.5 : 46.9
SBD 9	22.4 : 35.2 : 42.4

Table 1: XEDS data of Cu–In–Se films fabricated by liquid-phase deposition.

first nine films we have obtained from this ingot composition thus far. The XEDS (X-ray energy-dispersive) measurements were carried out on a Hitachi S-3000 SEM equipped with an EDAX detector.

All films were deposited onto quartz substrates which were sputter coated with 1  $\mu\text{m}$  of Mo followed by 100 nm of Cu. Therefore, since the same ingot was used for the deposited films, the only variable changed to produce films of varying composition was the thermal profile of the deposition itself. Ingots were either undercooled to just below the liquidus projection and then slid over substrate or alternatively, the samples were slid over substrate and the ingot consequently undercooled. The two methods have been shown (in the deposition of III-V semiconductors) to have different growth kinetics.

Thickness measurements have also been made on most deposited films. Different deposition times have resulted in different thicknesses of the films. For example, sample 2 was deposited for 15 min at 650  $^{\circ}\text{C}$  and resulted with an average thickness (measured by a Sloan DekTakII) of 2.7  $\mu\text{m}$ , whereas sample 5 was deposited for 2 h at 655  $^{\circ}\text{C}$  and resulted in an average thickness of 44  $\mu\text{m}$ . The higher deposition temperatures and longer deposition times resulted in films with better surface morphology.

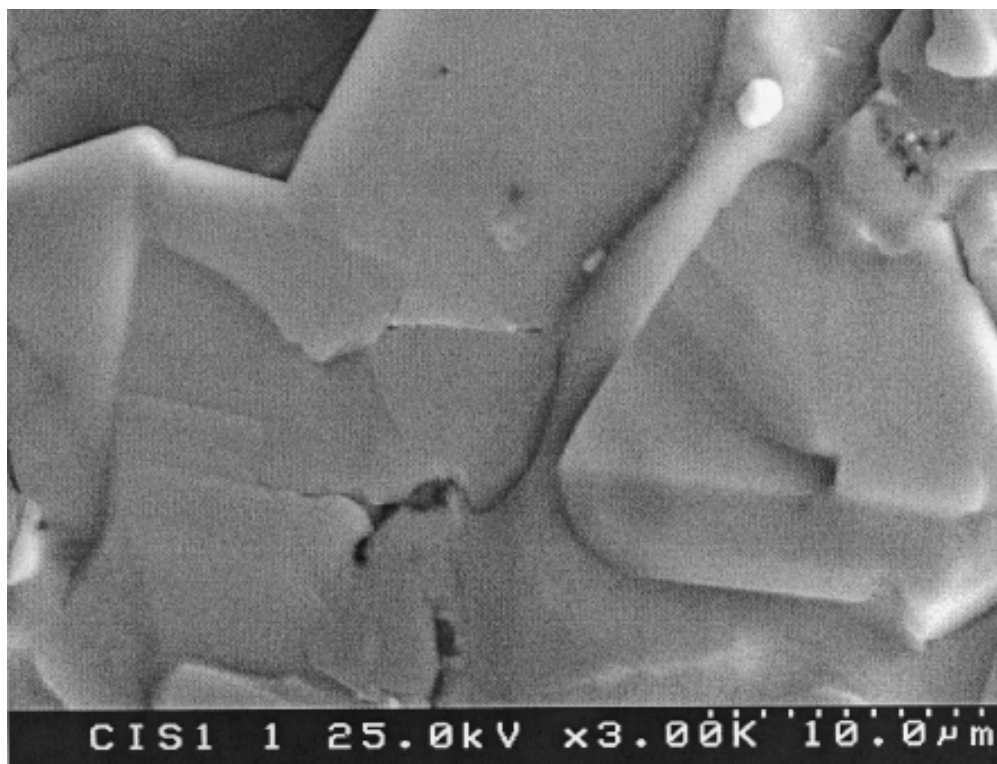


Figure 1: Surface morphology with large grains present.

Figure 1 displays the surface morphology of sample SBD 2, revealing the presence of large grains. X-ray diffraction was also carried out to prove the existence of the chalcopyrite crystal structure as well as verify the presence of the preferred growth plane for CIS. The chalcopyrite crystal structure possessed by  $\alpha$ -CIS grows preferentially on the (220)/(204) or the (112) growth plane. From Fig. 2 it is evident that the material has grown on the preferred (112). Sample SBD 4 proved

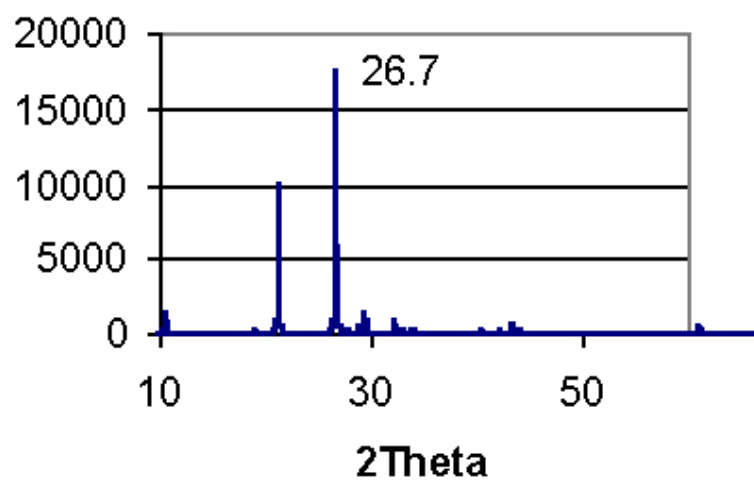


Figure 2: XRD pattern with strongest peak from the (112) growth plane (from sample SBD 3).

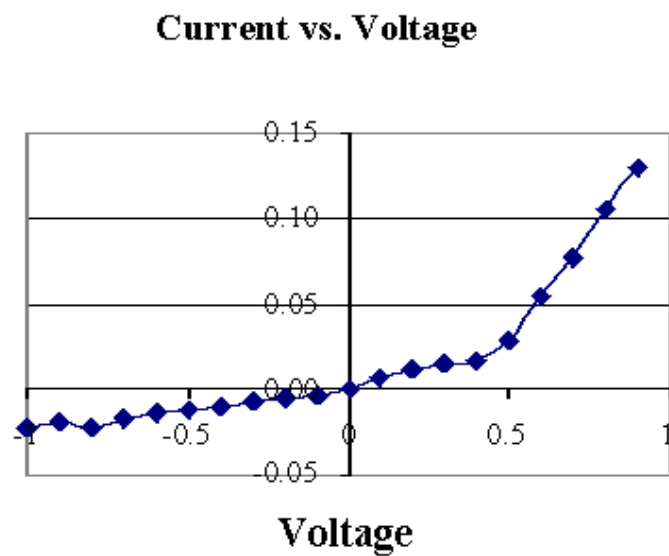


Figure 3: Current vs. Voltage curve revealing rectifying behavior.

to be one of the best samples grown thus far, with fairly uniform thickness of 55  $\mu\text{m}$  and a bulk composition very close to  $\alpha$ -CIS, it was made into a Shockley diode. The diode was made by evaporating aluminum contacts directly to the surface of the CIS film. Figure 3 is a graph displaying a current–voltage curve of the first diode made from this project.

In summary, since the set up of our “sliding boat” deposition chamber, we have successfully deposited  $\alpha$ -CIS films that exhibit both rectifying behavior as well as good surface morphology, essential for further fabrication of solar cell devices. Once film thicknesses and grain sizes can be better correlated to deposition conditions, we will be able to deposit absorber layers with significantly fewer structural defects than previously encountered by alternative PVD growth methods.